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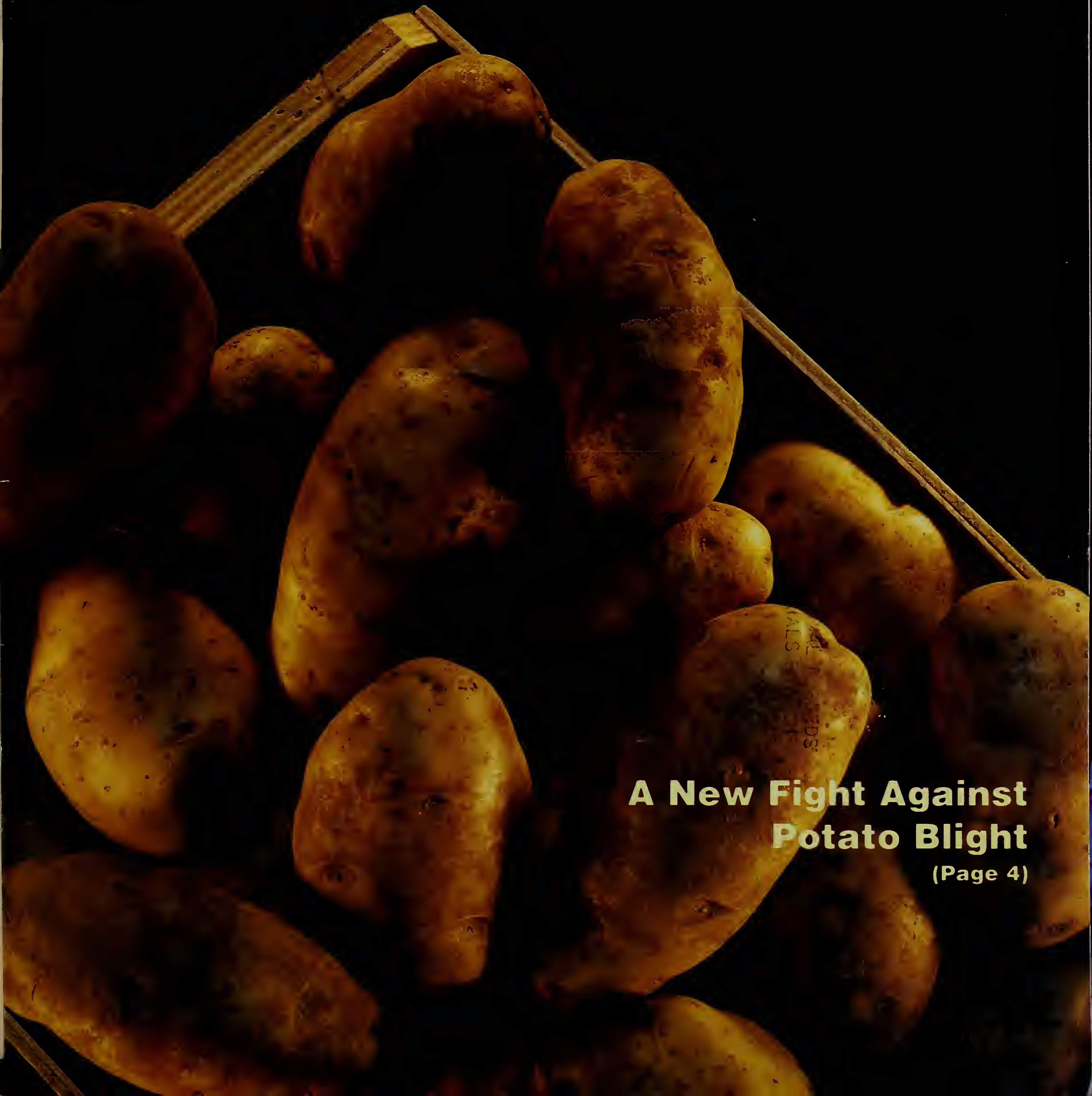

A New Fight Against Potato Blight

(Page 4)

One Potato, Two Potato...

Let's face it.

The potato is not of itself a glamorous vegetable—however many potato blossoms Marie Antoinette may have woven into her elaborate hairdo.

Potatoes are, by and large, lumpy and nondescript. They harken closely to their subterranean origins and seem to deserve their French name, "apple of the earth."

Yet, for millions of people, potatoes have meant survival. As a world food crop, they are among the top four in importance—along with wheat, rice, and corn. Highly valued in more than 100 countries, their annual production tops 290 million tons, worth well over $100 billion.

But like many good things, it took time for potatoes to gain their current popularity and significant place in the world's food larder.

Today's potato originated in South America thousands of years ago. Skilled Andean farmers learned how to cultivate its wild relatives at high elevations. They also learned how to select the kinds of potatoes that tasted and grew the best and to freeze-dry the tubers for storage as *chuño*.

The potato has come a long way since those early days. Europeans seeking gold and silver also packed the humble vegetable treasure as food for sailors homeward bound. Though word of its merits spread slowly, it eventually gained favor—first with Old World elite and eventually with commoners.

How could it have been otherwise? The potato tastes consistently good, whether prepared simply or imaginatively fluffed and sauced. And it's a nutritional powerhouse.

A plain baked potato of average size (150 grams) with skin delivers the consumer about 125 calories, no fat, and just a bit of sodium—along with significant amounts of vitamins C and B_6, copper, magnesium, niacin, pantothenic acid, phosphorus, potassium, thiamin, some good-quality protein, and dietary fiber.

Small wonder it became a culinary mainstay for large segments of the world's population. The potato was nutritious and satisfying eating, and in some societies, it even assumed a medicinal role. For example, raw slices were applied to help mend broken bones, cure headache and skin disease, and prevent rheumatism. Renaissance Europeans touted it as an aphrodisiac.

But some societies—notably the people of Ireland in the early 1800's—came to rely inordinately on the potato. That was perhaps understandable, because just a single acre could then support a family of six, allowing members as many as 10 pounds per day.

Such overreliance on a single food crop can lead to disaster—and did, when the potato blight caused by *Phytophthora infestans* invaded Ireland's potato fields. This particularly fast-spreading, destructive fungus brought starvation and death to about a million Irish in the mid-to-late 1840's and led to the mass exodus of survivors.

It is troubling to note that nearly 150 years after that devastating assault by *P. infestans,* the fungus once again looms in the agricultural picture. Its recent emergence—in a new and chemical-resistant form—in Europe, Mexico, Canada, and the United States is detailed in the story on page 4.

This time, however, growers won't be caught unawares. Scientists know what the fungus is and how it strikes. They are already preparing strategies to stymie *P. infestans'* advance. Some are trying to breed in natural resistance by crossing today's varieties with descendants of ancient ancestors or to achieve it through genetic engineering. Others hope to alter the fungus by unraveling its DNA secrets. Still others are looking at using chemicals as internal systemics and external protectants, along with exploring modified sanitation practices.

There's every reason to hope that research now under way will soon have the capacity to protect the valuable potato from this dangerous foe.

Linda R. McElreath
ARS Information

Agricultural Research

Cover: Fourth in importance as a food crop, potatoes mean survival to many of the world's people. Now an old-time foe—late potato blight—is making a comeback, and it's resistant to the main group of chemicals known to control it. Photo by Scott Bauer. (K5459-20)

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What Was Around Comes Around

Ken Deahl inherited his blue eyes from his Irish great-great-grandfather, who was forced from Ireland by the famine caused by the 1840's potato blight.

And 150 years later, potato blight is still affecting Deahl's life. Along with Agricultural Research Service colleagues and outside collaborators, he is avidly searching for a way to defeat *Phytophthora infestans,* the fungus that causes the disease. It's the most destructive disease of potatoes worldwide, and late blight also affects tomatoes.

"My grandfather talked of the 'mildew' that years ago devastated potatoes all over Europe," says Deahl, a plant pathologist/microbiologist with the ARS Vegetable Laboratory, Beltsville, Maryland. "When I told him that I'm working on the fungus that causes the blight, he was amazed that we're still seeking solutions to such an old problem."

But our generation has an even tougher foe to deal with than Deahl's great-great-grandfather had. The fungus has become resistant to the main group of chemicals known to control it. And there seems to be a new, more aggressive strain. These developments constitute a potential threat to potato production—in the United States and around the world.

Phytophthora infestans can destroy a potato crop—either in the field or in storage—in just a few weeks. Fungal attack first appears as brown specks on the plant; then a cottony film appears. Spores from these plants can be carried hundreds of miles by the wind to land on healthy potato plants. Cool, damp weather conditions encourage germination and infection.

Blighted stored potatoes turn a purplish color on the outside and appear shrunken, with a corky, reddish-looking rot on the inside. One infected potato is all it takes to destroy thousands.

And as though that's not bad enough, *P. infestans* infection also predisposes potatoes to other fungal and bacterial diseases.

The fungus can reproduce asexually, but there are also two mating types called A1 and A2, both of which must be present for sexual reproduction. Until recently, only A1 was known to exist outside Mexico, where Deahl says the pathogen is believed to have originated. The fungus was not such a threat when type A2 was restricted to Mexico.

SCOTT BAUER

ARS scientist Ken Deahl examines a potato leaf 3 days after it was infected with the fungus that causes late blight. (K5458-14)

"But in 1984, the A2 type was shown by Cornell University scientists to have migrated from Mexico to Western Europe," Deahl says. "Then in 1987, I found type A2 on potatoes in Athens, Pennsylvania."

It is the spores from these mating types of *P. infestans* that are of the most concern.

"Sexually produced spores, called oospores, have a protective cell wall that allows them to live in the soil, infected stems, and tubers and still be viable the following season."

Until 1990, *P. infestans* could be controlled with metalaxyl, a systemic chemical that protected potato plants. "But we've found strains of the fungus in the Pacific Northwest, British Columbia, Texas, California, Wisconsin, Pennsylvania, Florida, and Maine that resist the chemical," Deahl says. Potato plants are succumbing to this fungus, even when treated with metalaxyl.

To control metalaxyl-resistant strains, Deahl suggests that external chemical protectants could be applied along with systemics that protect the plant internally. Combined with better sanitation practices, such as immediate culling and destroying infected potatoes, protectants and systemics might control late blight—but would, of course, increase chemical use.

Building In Resistance

The only long-term solution is to find a potato variety that resists all strains of the pathogenic fungus, Deahl emphasizes.

"We know that wild potato species resist the fungus that causes blight," Helgeson explains. "But we can't breed those species with a cultivated potato because the seed tubers don't develop properly."

A germinating spore of the fungus that causes late potato blight. The germ tube is capable of penetrating susceptible leaves.

"We're pretty close to that goal," says ARS plant pathologist Robert Goth. "We have germplasm [potato plants] growing here in our greenhouses and in field plots in Maine that resists the fungus." Goth and plant geneticist Kathleen Haynes have been breeding potato lines at the Beltsville Vegetable lab and testing them for resistance to *P. infestans* for several years.

"We know that these lines resist the fungus, but we don't yet know how they will react to this new, more aggressive form of the pathogen," Goth says. He is continuing to test the new lines with emerging strains of *P. infestans*.

The original potato germplasm, which was resistant to the fungus, came from the International Potato Center in Lima, Peru.

"We made the first genetic cross with several breeding selections back in 1983," says Haynes. "Then the offspring were screened for late blight resistance, and the most resistant ones were again crossed with several breeding selections. We began evaluating the results in 1987, which means that some of this germplasm has been exposed to the fungus and resisted it for 10 years."

Haynes cautions that this material is only germplasm. Before germplasm can be released as a new variety, the potato plants must be productive, resist pests and diseases, and form tubers with good commercial attributes, such as size, shape, color, and processing quality.

"In 1993 yield tests, the new resistant selections yielded as well as standard varieties and had superior late blight resistance," she says. "This is a very positive finding for potato breeders."

Hybrids From Leaf Cells

For several years, John P. Helgeson, an ARS plant physiologist at Madison, Wisconsin, has been working to give potato breeders a source of genetic diversity.

"We know that wild potato species resist the fungus that causes blight," Helgeson explains. "But we can't breed those species with a cultivated potato because the seed tubers don't develop properly."

Even though a genetic cross of wild and cultivated species may look normal, the seeds are not viable, so they can't be used in further breeding work, he says.

With the help of biotechnology, Helgeson came up with an answer. He fused leaf cells from a wild potato species with leaf cells from a cultivated variety to develop what is called a somatic hybrid. The resistant wild species, *Solanum bulbocastanum*, came from the area of Mexico where *P. infestans* is thought to have originated.

These lines are fertile and as resistant as the wild species are to virulent types of the fungus, Helgeson reports. "We'd like breeders to evaluate these lines."

Helgeson says that in an emergency, the resistant material could possibly be ready for breeders in about 2 years. In conjunction with the University of Wisconsin Agricultural Experiment Station, Helgeson is

Ken Deahl (right) and West Virginia University scientist Robert Young visit a field of late-blight-resistant potatoes in Toluda Valley, Mexico.

also testing the lines against early blight, another similar fungal disease that affects plants early in the growing season.

In Reedsville, West Virginia, Robert Young field-tests somatic hybrids selected at West Virginia University, where he is a plant pathologist in the College of Agriculture and Forestry.

"Regeneration through somatic hybrids gives us an additional measure of resistance," he says. "We've collected plant material from Mexico that resists both types of the fungus and have planted hybrids here in Reedsville. Some plants show resistance but not immunity, so more work is needed."

Young, who collaborates with Deahl, is testing germplasm supplied by the ARS Vegetable lab, as well as looking for the genes in wild potato species that resist *P. infestans.*

SCOTT BAUER

Ten days after being infected, this potato shows late blight's severe damage. (K5455-11)

Epidemiology of the Fungus

Paul Tooley, a plant pathologist at ARS' Foreign Disease-Weed Science Laboratory in Frederick, Maryland, evaluated some of Helgeson's new potato lines for resistance to blight.

Tooley has spent more than a decade studying the epidemiology—the factors governing the absence or presence—of *P. infestans.* "This pathogen changes so rapidly it seems to overcome any type of resistance. By looking at its genetic variation, we're hoping to better understand how the pathogen works," he says.

By comparing the DNA content of the pathogen collected from different regions, Tooley found that the Mexican fungus is primarily diploid, meaning that it carries two copies of each chromosome. Some other areas of the world harbor fungal strains that are tetraploid, or polyploid, meaning that they have four or more copies of each chromosome. These regional

SCOTT BAUER

Technician Connie Baker inspects stock cultures of the late blight fungus stored for comparisons of the different populations in North America. (K5459-3)

differences indicate that the fungus has a very high potential for genetic adaptation.

Tooley looks at the basic genetic makeup of the fungus by using enzyme markers called isozymes, along with other DNA-based markers that will help determine how the fungus achieves genetic variation.

When the A2 mating type of the fungus escaped from Mexico, it was these isozymes and DNA markers that helped identify the appearance of new *P. infestans* populations in Europe and the United States. "With these markers and genetic techniques, we hope to eventually identify the genes that cause the fungus to resist fungicides," Tooley says. "It's impossible to identify the type of fungus by sight, so we use DNA fingerprinting."

This procedure was applied by scientists at Cornell University, where Tooley worked before coming to ARS to continue research on the basic biology and epidemiology of the pathogen.

Fingerprinting works like this: Tooley takes random fragments of DNA extracted from a given *P. infestans* strain and clones them into a bacterium. These fragments are radioactively labeled and used to probe other strains' DNA that has been enzymatically cut into small pieces and separated on an agarose gel that has been subjected to electric current. He then transfers the fragments to a nylon membrane where the labeled probe hybridizes with them. The DNA fragments with sequences similar to that of the probe will bond with the probe, producing a pattern of bands on x-ray film.

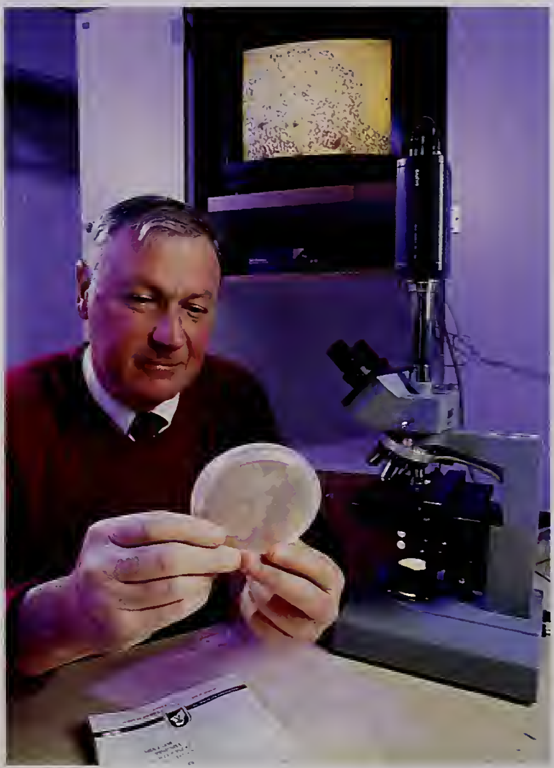
A probe developed at Cornell University gives DNA fingerprint patterns highly specific to a given strain of the potato blight fungus.

"These fingerprint patterns enable scientists to trace certain strains of the fungus across continents. It was DNA fingerprinting that allowed Cornell scientists to determine that most of the old population of potato blight in the United States and in other countries besides Mexico was caused by a single strain of *P. infestans*," Tooley says.

SCOTT BAUER

Plant pathologist Robert Goth (right) and geneticist Kathleen Haynes discuss the use of several potato varieties in breeding for late blight resistance. (K5457-1)

SCOTT BAUER



A culture of *Phytophthora infestans* being studied by WSU scientist Robert Young is used to infect laboratory potato and tomato plants. Television monitor at rear displays a magnified cross section of a tomato leaf. (K5453-19)

He explains that in recent years many new strains of the pathogen, including the A2 mating type, have become established, greatly complicating blight control. Some of the new strains resist fungicides and may mate with strains already here and produce the long-lived oospores.

Working with Cornell and the Wageningen Agricultural University in the Netherlands, where both types of the fungus are established, Tooley is helping to develop a genetic map of the fungus.

"We've also identified the presence of double-stranded RNA in *P. infestans,* which often indicates infection with a fungal virus. dsRNA provides a novel marker for genetic studies and for monitoring pathogen movement. It gives us one more diagnostic tool for studying and tracing the origin of this elusive and destructive pathogen," Tooley says.—By **Doris Stanley,** ARS.

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Yeasts and Bacteria Battle Decay

Ever reach for a few plump grapes or a beautiful, sunny peach in your fruit bowl and have your fingers sink into a rotting soft spot? You've just encountered the work of a group of molds that cause fruit rot.

Although fungicides can control most fruit rots, their use is causing concerns about possible effects on human health and the environment. It's these concerns that have caused some agricultural chemicals used in the past to no longer be approved for fruits and vegetables.

While the search for replacement chemical controls continues, Agricultural Research Service scientists are looking for a more benign way to keep fruit fresh and fit.

At the sprawling Appalachian Fruit Research Station near Kearneysville, West Virginia, plant pathologists Wojciech J. Janisiewicz and Charles L. Wilson are focusing on microorganisms such as yeasts, bacteria, and natural fungicides from plants and animals.

A Pink Yeast To Stop Blue Mold

On the surfaces of fruits, they've found several naturally occurring yeasts that prevent rot pathogens from attacking and decaying the fruit. The yeasts outcompete the pathogens for food and space. These so-called yeast antagonists may attach themselves to the walls of the pathogens, where they produce wall-degrading enzymes.

KEITH WELLER

Plant pathologist Wojciech Janisiewicz compares Golden Delicious apples 3 months after being protected against blue and gray molds by a colorless, tasteless bacterium. (K5427-14)

Janisiewicz has discovered a pink yeast—occurring naturally on the surface of pears—that controls decay in stored apples.

"This yeast reduced blue mold on apples up to 100 percent and gray mold up to nearly 80 percent," Janisiewicz says. These molds are major diseases of stored fruit. The yeast works well in low concentrations and shows promise for commercial development.

Since pink yeast, *Sporobolomyces roseus,* is ubiquitous in nature and present on most fruits, Janisiewicz thinks it would have little problem being accepted by consumers and regulatory agencies for direct application to fresh produce. But further research and testing are necessary.

"This yeast worked as well as fungicide treatments on fruit removed from storage after 3 months," Janisiewicz says. "Surprisingly, in fruit stored for 6 months, yeast-treated fruit had less rot than that treated with a fungicide."

Control of fruit molds with *S. roseus* was consistent in all experiments, regardless of how the compound was applied, he says.

Another advantage of the yeast as a biocontrol for rots is that when applied, it multiplies by 100-fold in the first 48 hours. Nutrients from fruit wounds, coupled with high storage humidity, provide ideal growing conditions for the yeast. Janisiewicz has received a patent for this yeast for use as a biocontrol agent against fruit rot.

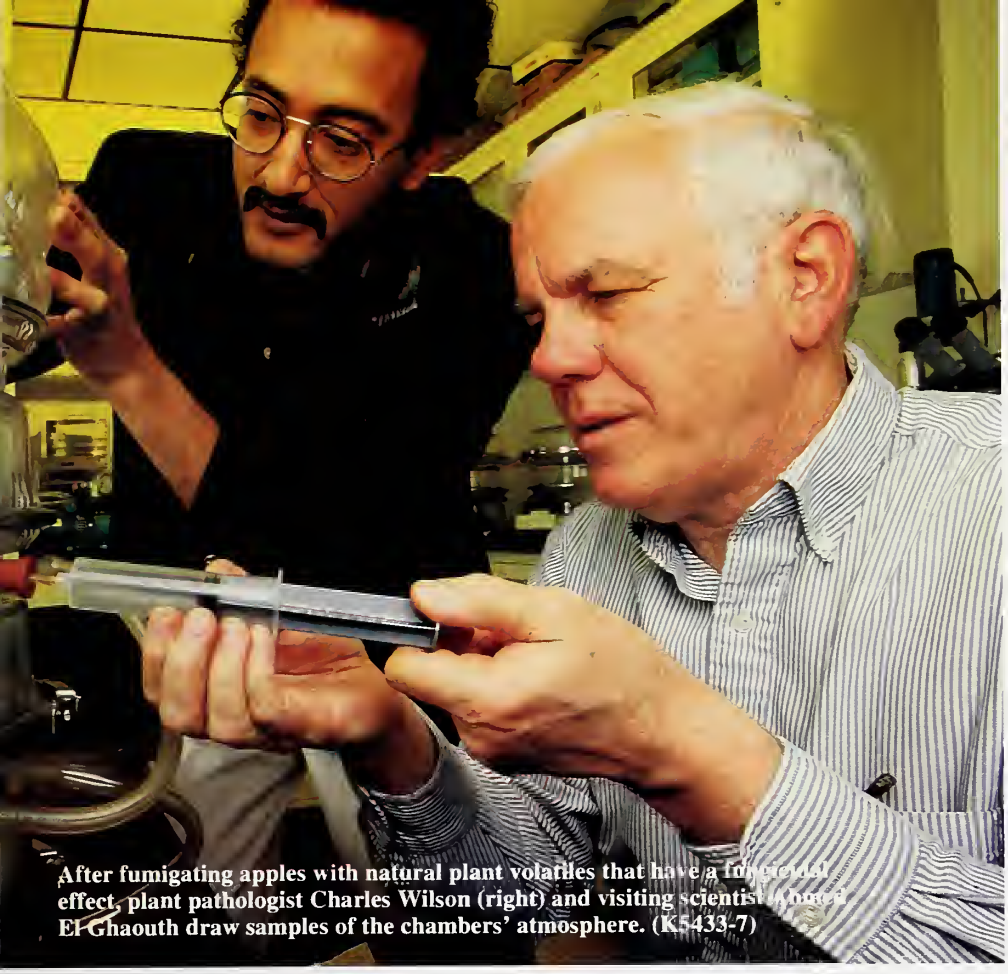
KEITH WELLER

A Similar Treatment for Flowers

Cut roses are now beneficiaries of natural, pathogen-fighting organisms. Janisiewicz is supplying Penn State University scientists with pyrrolnitrin—a compound isolated from the bacterium *Pseudomonas cepacia*—to control blossom blight on cut roses. This blight, caused by the same fungus that generates gray mold on apples and pears, is a widespread, destructive disease on greenhouse-grown roses and many other cut flower crops.

Rose growers now use fungicidal sprays or postharvest flower dips to prevent blossom blight, which often escapes detection at harvest. But the disease develops quickly under the moist conditions of storage and shipment. And blight resistance to fungicides is widespread.

In laboratory tests, pyrrolnitrin gave about 90 percent blight control, which is comparable to that achieved



After fumigating apples with natural plant volatiles that have a fungicidal effect, plant pathologist Charles Wilson (right) and visiting scientist Ahmed El Ghaouth draw samples of the chambers' atmosphere. (K5433-7)

by fungicides. Leaves and buds showed no adverse effects from the treatment.

"Pyrrolnitrin is a potential alternative to the synthetic fungicides that flower growers now use, and it may be particularly useful in preventing fungicide-resistant pathogens," Janisiewicz says. The compound isn't available commercially and hasn't yet been registered for use on roses.

Janisiewicz and ARS chemist James M. Roitman from Albany, California, hold a patent for the use of *Pseudomonas cepacia* and pyrrolnitrin.

Janisiewicz holds a patent for another beneficial bacterial organism. This organism, *P. syringae* isolated from apples, also controls fruit rots. Already licensed for use by Eco-Science of Amherst, Massachusetts, its formulations have been successfully tested under commercial conditions around the country.

"Using sugar analogs and amino acids, we've found a way to manipulate the fruit surface that makes it more favorable to growth of the beneficial yeasts and bacteria," Janisiewicz says.

Enzymes for Plant Defense

Ahmed El Ghaouth, a visiting scientist from Canada, found that when applied to fruit, yeasts stimulate the production of several defense responses. These include the formation of structural barriers and the production of chitinase, an enzyme that's part of the plant's natural defense against fungal pathogens.

El Ghaouth, with the Center for Horticultural Research, Laval University, Quebec, has been collaborating with Wilson on this project at Kearneysville for the past year. El Ghaouth has found that chitosan—a naturally fungicidal compound derived from crustaceans like shrimp and crabs—is a good carrier for yeast antagonists. Chitosan, he says, also turns on production of defense enzymes in the fruit.

Under a Biotechnology Research and Development Corporation agreement, El Ghaouth will work at Kearneysville for the next 3 years to develop a bioactive coating that will contain chitosan, an antagonistic yeast, and natural fungicides to protect fruit. This combination could be expected to present a highly complex disease-deterrent barrier.

By adding a sugar (2-deoxy-D-glucose) to the antagonistic yeast *Candida saitoana*, Wilson and El Ghaouth have come up with a new biocontrol agent to protect peaches and apples from postharvest rots. In laboratory tests of apples treated with the yeast-sugar combination, after 16 days, 80 percent completely resisted the *Botrytis cinerea* rot pathogen. Scientists have applied for a patent on the yeast-sugar combination.

These yeasts do not produce antibiotics but instead compete with the pathogen for survival.

It is well known that plants naturally contain a number of effective fungicides, but none are commercially available, Wilson says. So he is hoping to isolate and identify their biologically active ingredients.

He has already found fungicidal properties in several volatile compounds produced by ripening peaches. Three of these completely stopped the growth of two major fruit rot fungi that attack peaches, *Monilinia fructicola* and *Botrytis cinerea*.—By **Doris Stanley,** ARS.

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A Cleanup for Poultry Litter

Alum—a medicinal compound with more mouth-puckering power than any green persimmon—could be the prescription needed for a healthier environment, healthier chickens, and a better bottom line for farmers, says ARS soil scientist Philip A. Moore, Jr.

An astringent long used to stop bleeding, alum is one of several compounds that Moore and University of Arkansas scientists tested as possible additions to poultry litter, that often-odoriferous conglomeration of bedding material and manure left on poultry house floors by broiler flocks gone to market.

"After the chickens are taken out, the litter is removed from the poultry houses," says Moore, who is based at the ARS Poultry Production and Product Safety Research Unit in Fayetteville, Arkansas. "That litter is usually applied to land as fertilizer, since it contains substantial amounts of nitrogen, phosphorus, and other essential plant nutrients."

But this theoretically inexpensive homegrown fertilizer can carry a high environmental cost. While the litter is still on poultry house floors, its nitrogen content tends to volatilize—evaporate into ammonia—leaving all of the phosphorus.

"The grain that the birds eat has a ratio of about eight parts nitrogen to one part phosphorus," says Moore. "But when nitrogen volatilizes, you wind up with a ratio of two to one, or occasionally even one to one."

Litter is applied to land as fertilizer at rates based on its nitrogen content. So, spreading enough litter to provide sufficient nitrogen to the land can result in serious phosphorus overloads—which is bad news for nearby waterways.

"Phosphorus is the number-one element for accelerated growth of algae in streams and rivers," explains Moore. "There have been studies showing extremely high phosphorus concentrations in runoff water from pastures receiving low-to-moderate levels of poultry litter. And most of that phosphorus in the runoff water—80 to 90 percent—is dissolved-reactive phosphorus, the form easiest for algae to take up."

To stop the runaway phosphorus, Moore began working in 1992 with University of Arkansas scientists David M. Miller, Tommy C. Daniel,

DAVID NANCE

Soil scientist Philip Moore, Jr., and research assistant Beth Green at Beaver Lake, Arkansas, repeat a study done 20 years ago to see if levels of phosphorus and other nutrients have changed. (K5477-1)

Litter is applied to land as fertilizer at rates based on its nitrogen content. So spreading enough litter to provide sufficient nitrogen can result in serious phosphorus overloads.

and Dwayne R. Edwards to find compounds that could be mixed with poultry litter to bind its phosphorus into a mineral form that is nonsoluble and immobile in soil.

In addition to alum, the research team tested mixtures of sodium aluminate, calcium oxide (quicklime), calcium hydroxide (slaked lime), calcitic and dolomitic limestone, gypsum, ferrous and ferric chloride, and ferrous and ferric sulfate.

They mixed fresh poultry litter with the various compounds in glass bottles and incubated them in the laboratory at 77°F for a week. Then they blended the mixtures with deionized water and measured the soluble phosphorus.

"A combination of lime and alum removed virtually all of the soluble phosphorus from the solution," Moore reports. The other compounds lowered water-soluble phosphorus levels to a lesser degree, depending on the rates used—with the exception of the limestones, which had very little effect.

In other laboratory tests, alum with and without lime also greatly reduced nitrogen evaporation into ammonia, Moore says.

"For that study, we mixed fresh litter with various compounds in airtight plastic containers," he recalls.

"We used 11 different treatments including calcium hydroxide, alum, ferrous sulfate, and a product sold commercially to reduce nitrogen volatilization. We measured the amount of ammonia volatilized over a 42-day period, the typical length of time it takes to grow a broiler to market size. When we used alum at the rate of 200 grams per kilogram of litter, the nitrogen evaporation to ammonia was reduced by 99 percent."

Lower ammonia levels in poultry houses mean healthier birds.

"Ammonia can actually tear holes in the birds' mucous membranes. Then disease pathogens get in those holes," Moore notes. "In one study done in 1964, chicks were exposed to Newcastle disease virus. Some of the chicks were placed for 72 hours in an environment with 20 parts per million of ammonia, and other chicks were in an ammonia-free environment.

"Only 40 percent of those in the ammonia-free environment became infected with Newcastle disease, but 100 percent of the chicks in the environment with ammonia were infected. High ammonia levels also reduce the birds' appetite and can cause blindness."

DAVID NANCE

ARS soil scientist Philip Moore, Jr., (left) and University of Arkansas scientist David Miller examine two beakers of runoff water from plots where poultry litter had been applied. The clearer water is from the plot treated with alum, which binds phosphorus into an insoluble form. (K5477-2)

Poultry producers hoping to avoid this damage can increase ventilation in poultry houses, but cold air pumped in during winter months must be heated, adding greatly to production expenses.

"In one study done in 1988, the scientists calculated that if the outside temperature is 45°F, the cost of producing broilers goes up 5 cents per pound when ammonia concentrations in the house go from 25 parts per million to 85 parts per million," says Moore.

"In a normal poultry house with 19,000 birds weighing about 4 pounds each, this would come to about $3,800 per flock. By comparison, we estimate the cost of enough alum to treat a poultry house, if bought in bulk, at about $440."

Poultry producers can recoup a significant portion of that $440 through the value of their nitrogen-rich litter as fertilizer, according to Moore. "The nitrogen you save in your litter is about 1,000 pounds for each flock grown out, and that's worth about $300," he says.

The improved litter-fertilizer also boosts agricultural production on the fields receiving it, Moore points out.

"We did a field study where we applied litter to plots of fescue at 5 tons per acre, the recommended rate in Arkansas, followed by simulated rainfall at a rate of about 2 inches per hour," he says. "We had plots with plain litter, litter plus alum, and litter plus ferrous sulfate.

"We saw an 87-percent reduction in phosphorus runoff in the plots with litter plus alum. But it's also interesting to look at the forage yields: 2,103 pounds of fescue produced per acre on the plots with litter plus alum, compared with 1,761 pounds per acre on the plots with litter plus ferrous sulfate, 1,647 on the plots with plain litter, and 653 pounds per acre on the plots that didn't get any litter.

"Chicken litter is one of the best fertilizers in the world," Moore concludes. "As long as we can use this resource wisely, we should use it. But it takes some special management to get the most from litter."—By **Sandy Miller Hays,** ARS.

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In a sunny greenhouse atop the 11-story Children's Nutrition Research Center in the heart of Houston's Medical Center, Mike Grusak presides over a marriage of sorts. He is uniting plant breeders and geneticists with experts in human nutrition. His goal is to ensure that tomorrow's crops will both answer farmers' needs—as for better growth habits, yields, or resistance to insects and diseases—and provide more of the nutrients needed by infants, children, and adults in a readily absorbable form.

Traditionally, breeders have paid little attention to increasing these nutrients—vitamins, minerals, amino acids, and other health-promoting substances—in food crops. And nutritionists have focused on individual nutrients rather than the grain, fruit, or vegetable that supplies them.

"I'm trying to promote the idea of studying whole food as a source of nutrients," says Grusak, who is a new breed of plant physiologist.

This entails following an element such as calcium, iron, or nitrogen along a tortuous path from outside the plant's roots into its edible portion—the soybean seed or the lettuce leaf, for instance—and, finally, into the bloodstream of the consumer.

Grusak uses stable isotopes—such as calcium-42 or nitrogen-15—to label the mineral or amino acid under study, right in the plant. These naturally occurring isotopes are heavier or lighter than the common version of the mineral. So researchers can follow their "footprints" by putting samples in a mass spectrometer, which separates chemicals by minuscule changes in weight. And because they are nonradioactive, they are harmless to infants and children in the studies.

JACK DYKINGA

In his rooftop greenhouse, plant physiologist Michael Grusak checks root growth on iron-accumulating mutant pea plants. Other hydroponically grown plants include green beans that take up stable-isotope calcium from their nutrient solution. (K5464-15)

Rooftop Greenhouse Provides

Under the greenhouse glass, mutant pea plants climb stakes while green beans shoot up in enclosed growth chambers, their roots dangling in a precisely defined growth solution circulated through almost-concealed highways of PVC pipe.

Grusak and his assistant, Shahrbanu Pezeshgi, developed the hydroponics system to recirculate the growth medium "so we don't waste any isotope; they're very expensive," he says. "With this system, we can monitor how much calcium is being absorbed by the green beans so we know how much to replace each day." And he establishes at what stage in a plant's development to add the isotope so that most of it gets into the edible portion.

He is collaborating with Steve Abrams, a medical doctor at the center, to determine how much of the calcium in the green beans gets into teenage girls and boys. They want to know how much of the beans'

Nutrition Answers

calcium is absorbed—a concept known as bioavailability. The researchers are looking for a way to provide the 1,200 milligrams of calcium this fast-growing age group needs but may not be getting from dairy products.

Abrams says adolescents today drink an average one-third less milk than they did before 1950. Many teenage girls have stopped drinking milk altogether, he says. If they're not getting calcium from other sources, they're increasing their risk of osteoporosis later in life.

The best way to prevent the disease is to lay down more bone before and during puberty, he says, noting that research shows that girls stop making bone by age 15. That is several years earlier than previously thought.

The current Recommended Dietary Allowance calls for increasing girls' calcium intake to 1,200 milligrams per day for ages 11 through 24. He has found that bone formation in girls peaks during the 4 or 5 years surrounding puberty. "Girls from about age 9 through 14 would benefit most from the extra calcium," says Abrams. "After that, it may not be as beneficial."

He and Grusak hope that green beans can take up some of the slack. They aren't the richest vegetable source of calcium—kale and other leafy vegetables are, Grusak says. But they're more popular among this age group. About 25 percent of U.S. teenagers eat green beans.

Meanwhile, Grusak is also collaborating with University of Wisconsin researchers on a breeding project that could ultimately produce a high-calcium, garden variety green bean. "Although various factors influence a mineral's bioavailability," he says, "we assume that absorption may be increased if the mineral content could be increased in a food source."

Last summer, plant breeder James Nienhuis and colleagues at Madison grew 60 varieties of green beans in Wisconsin in hopes of finding a few high-calcium varieties. They are currently being analyzed by Grusak.

If any should score high in calcium, he will grow them in his hydroponic system to be labeled for future bioavailability studies.

And if any of these increase calcium levels in the volunteers, the plants will be used in breeding work to incorporate high-calcium genes into varieties that have the best horticultural and food quality traits.

The breeding program will go one step further, he adds. "It will help us identify the genetic basis for the elevated calcium content. In addition, we will use the high-calcium varieties, along with low-calcium ones, to study the physiological basis for calcium content." For instance, do the plants absorb more through the roots or send more of what they absorb to the bean?

JACK DYKINGA

Volunteers Erica Croon (right) and Susan Schanler consume stable isotopes of calcium added to the milk and incorporated into the green beans through the hydroponic system. (K5460-1)

But he's not betting all his isotopes on green beans. "We're going to look at broccoli, too."

The Pea Plant That Self-Destructs

The mutant pea plants thrive and produce seed in Grusak's rooftop greenhouse because he limits the iron in their growth medium. Grown in the field, these mutants don't know when to "say no" to iron. They take up way too much and die from toxic levels before they produce seed. They can accumulate a thousand times more iron in their leaves than a normal pea plant, but they don't put any more iron in their seeds.

His idea in studying the mutant is to learn how to get more iron or other minerals into the edible portion—the seed . . . and not just in peas. All cereal grains, legumes, and some vegetables are seeds, he points out. "As people turn to healthier diets containing more plant foods, we've got to meet demand for more nutrients in those foods."

He says two factors determine how much mineral gets into the seed: How much the roots absorb in a given time, and how much the plant transports into the seeds. "We want to understand what regulates the rate-limiting transport processes for iron and attempt, through classical and molecular genetic approaches, to modify the plant and enhance the seed iron content."

So far, he has scientifically described the iron reductase system that limits how much of the mineral—as free iron—moves into the roots. Once absorbed, however, the iron doesn't simply head straight for the seed through the plant's waterway, known as the xylem transport system. It has to transfer to the sap, or phloem transport system, and that's where things get sticky. The sap doesn't accept the free iron as a passenger, he says. It apparently has to hook up with a kind of "escort" molecule before it gains admittance. So the amount of iron that gets into the seed depends on how much escort is available to transport it.

"The shoots are communicating with the roots, telling them how much iron is needed," Grusak explains. "If we can increase how much iron goes into the seed by boosting this transport system, the roots may automatically take up more iron without our having to tinker with the root reductase system."

He hasn't identified the escort molecule yet. But when he does, plant geneticists can search for the genes that direct its production.—By **Judy McBride,** ARS.

Michael A. Grusak and Steven A. Abrams are at the USDA-ARS Children's Nutrition Research Center, 1100 Bates, Houston, TX 77030; phone (713) 798-7000, fax (713) 798-7098. ◆

JACK DYKINGA

Plant physiologist Michael Grusak and Steven Abrams, M.D., review calcium isotope analysis from mass spectrometer. (K5462-1)

It Pays To Irrigate Plantains and Bananas

Semiarid areas in the Tropics typically only get about 37 inches of rain a year—not enough to grow a profitable banana or plantain crop. But drip irrigation more than pays for itself when it comes to growing these fruits in Puerto Rico's semiarid areas.

A 1990-93 study by Agricultural Research Service scientists is the first to document the cost effectiveness of irrigating these important fruit crops, worth $53 million a year to farmers in Puerto Rico.

"Banana is a water-loving plant. It responds very well to drip irrigation in low-rainfall areas," says agency plant physiologist Ricardo Goenaga, who is based at the Tropical Agriculture Research Station in Mayaguez, Puerto Rico. ARS horticulturist Heber Irizarry and agricultural engineer Bruce Coleman of BECA, Inc., Coamo, Puerto Rico, also participated in the study.

Goenaga estimates that about 50,000 acres of semiarid land with irrigation systems have become available with the decline of the sugarcane industry. This acreage can be partly used to expand the local plantain and banana crops, because soils are deep, very fertile, and flat, thus facilitating mechanized field operations.

Growers who supplement rainfall with drip irrigation on a 50-acre farm can make gross profits of about $205,000 for plantains and up to $374,000 for a first-ratoon crop of bananas, according to the study.

A banana planting yields several crops—the first being the fruit that grows from the original planting or plant crop, followed by subsequent ones from shoots called ratoons. The first ratoon crop usually yields more than the first plant crop.

Profits are based on using drip irrigation to replace, on a one-to-one basis, water estimated to be lost through soil evaporation and plant transpiration.

SCOTT BAUER

Bananas (left) and plantains. Drip irrigation would profit growers of this $53 million Puerto Rican crop. (K5452-16)

Total water and energy costs for a 50-acre planting were estimated at just under $4,900 per year, including $3,800 for energy and $1,100 for water. Goenaga estimates that the capital cost of installing a 50-acre drip irrigation system ranges from $69,000 to $84,000, depending on the quality of the pumps and tubing. In drip irrigation, water is pumped from underground wells or surface water supplies into tubes and trickles through small openings onto the soil. This conserves water, compared to overhead sprinkler irrigation.

About 50,000 acres of semiarid land with irrigation systems have become available with the decline of the sugarcane industry.

"A grower needs to get at least 28,000 pounds of bananas per acre to have a profitable crop," Goenaga says. "This level of irrigation almost doubled that—to 50,443 pounds per acre for the first-ratoon crop."

Increasing irrigation 25 percent beyond what is lost from evaporation and transpiration increases profits even further. The extra water and energy cost only about $1,200 per year but increase gross plantain profits by $7,100 and first-ratoon banana profits by $72,000.

"We were very surprised that the increase in yields would be so high from adding 25 percent more water," Goenaga says. "The additional irrigation more than pays for itself."—By **Sean Adams,** ARS.

Ricardo Goenaga is at the USDA-ARS Tropical Agriculture Research Station, P.O. Box 70, Mayaguez, Puerto Rico 00681-0070; phone (809) 831-3435, fax (809) 832-1025. ◆

Insect I.D.'s Now at Your Fingertips

SCOTT BAUER

When port-of-entry agricultural inspectors find an insect they can't identify, they turn to Agricultural Research Service entomologists for help.

The ARS Systematic Entomology Laboratory has been America's primary source of information on the classification and identification of agriculturally important insects and mites for more than a century.

"The information SEL scientists provide to users seeking insect identification has been crucial to the success of U.S. agriculture," says Manya Stoetzel. She is in charge of the laboratory, located at the Beltsville (Maryland) Agricultural Research Center.

Most of the SEL scientists work at the U.S. National Museum of Natural History in Washington, D.C., where the national collection of insects is located.

Such identifications help keep potential insect pests from accidentally entering the United States. With this proverbial "ounce of prevention," countless dollars in pest control and eradication costs can be saved.

However, speed of insect identification is vital to many users of the information. For example, USDA's Animal and Plant Health Inspection Service (APHIS) inspectors are sometimes faced with having to identify a strange or unknown insect while a valuable cargo of fruit or vegetables lies at anchor offshore, unable to be unloaded.

"Every hour spent on this identification process can potentially cost importers thousands—and sometimes millions—of dollars in produce deterioration and associated costs, such as storage losses," says Rebecca Bech, chief of APHIS' National Identification Branch, Division of Plant Protection and Quarantine, in Hyattsville, Maryland.

"But the alternative of possibly allowing a new pest into the country is not one of our options. We've got to move fast and yet be as accurate as possible in our decision about the insect's identity. If it's a pest not known to occur in the United States or is of limited distribution, the cargo must be refused entry, destroyed, or treated to lessen the risk," Bech says.

"From the viewpoint of agriculture, the entry of a foreign insect could lead to serious economic damage to our crops. The consequences of this potential damage outweigh the immediate economic value of the cargo," she adds.

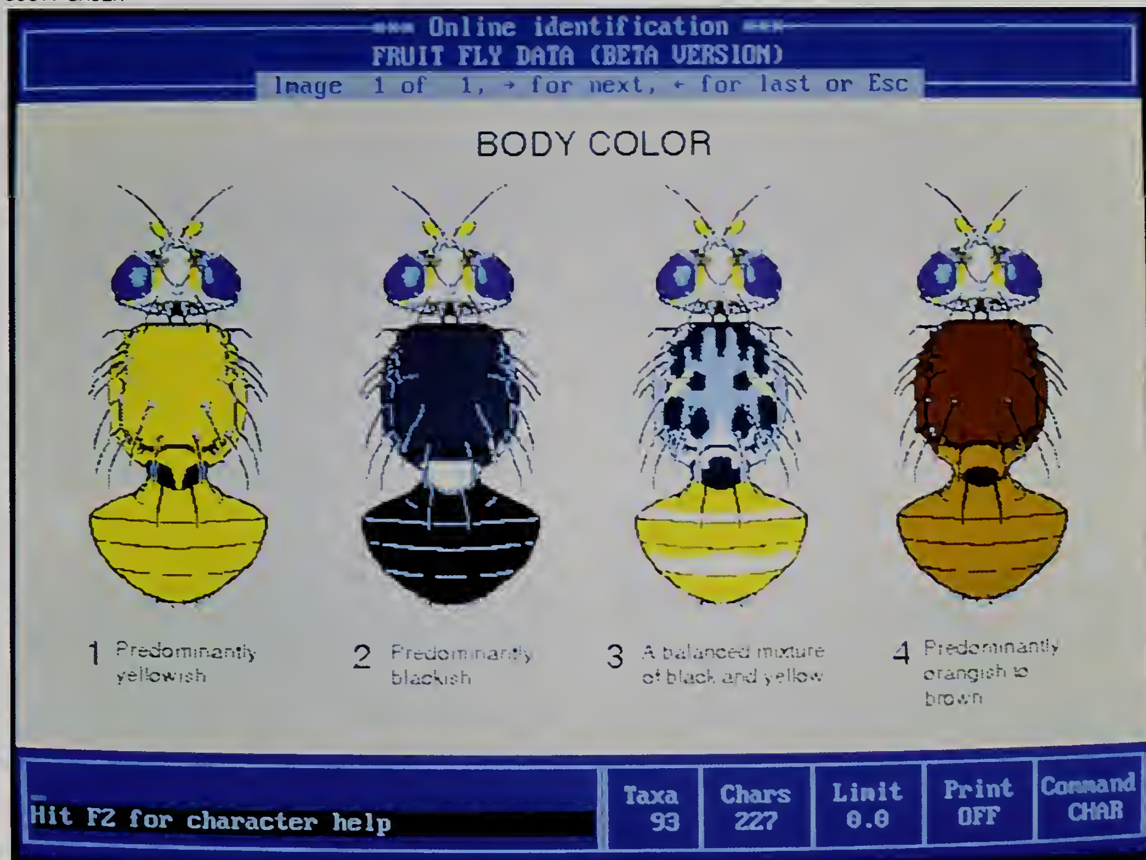
According to Bech, in 1992, APHIS intercepted over 37,000 quarantine-significant insects on commodities entering the United States. About 4,000 of these were fruit flies.

Each year, SEL scientists get several thousand requests—many from APHIS colleagues—for urgent insect identifications. Often, the suspect insect is one of 4,500 species from about 500 genera of fruit flies that have been identified worldwide, Stoetzel says.

SEL fruit fly expert Allen Norrbom says, "Among fly families in the world, fruit flies are the most costly to agriculture. One of the worst of these is the Mediterranean fruit fly,

◀ **Entomologist Chris Thompson (right) and technical information specialist Lynn Carroll select specimens of *Bactrocera* flies for inclusion in the computerized fruit fly identification system. (K5444-6)**

SCOTT BAUER



▶ **This is one of the beginning screens displayed by the new fruit fly identification system. If the unknown fly being identified had a balanced mixture of black and yellow, selecting No. 3 on the screen would immediately eliminate 152 of the 193 fly families considered pests. Subsequent screens displayed would further narrow the choices until an exact identification could be made. (K5446-12)**

which attacks many important crops, among them U.S. citrus valued at almost $2 billion annually. In 1980 and 1981, USDA and the California Department of Food and Agriculture spent over $100 million to eradicate a medfly outbreak. Today, the cost would be considerably higher because of inflation and stricter environmental controls."

Let Your Fingers Do the Walking

Norrbom recently helped publish a new 571-page handbook on fruit flies (Tephritidae) of North America in collaboration with retired entomologists Richard Foote and Louie Blanc.

According to Stoetzel, the handbook is "a major contribution to information on biotic diversity, adding immeasurably to what we know about Tephritidae in the United States and Canada. It will serve as a valuable guide for decisionmaking on pest control efforts."

Besides detailed descriptions, drawings, and photographs of fruit fly species, the handbook ties together all kinds of information about host crops and provides maps showing the geographic distribution for each species.

"However, since the time of publication, even more about the family has become known, so some information is already incomplete," Stoetzel says.

But thanks to new computer technology, this will not happen again. SEL entomologists F. Christian Thompson and Lynn Carroll, in collaboration with fruit fly expert Norrbom and specialists from England and Israel, are putting the finishing touches on the first computerized expert system and database of true fruit flies. It illustrates and describes more than 190 species, all economically important.

The database contains the critical information—about which fruit the fly maggots eat, where the fly occurs, and where more information can be found—for more than 5,000 fruit flies. The team spent 5 years on the project.

"Now, scientific experts on fruit fly species of the world can share their knowledge electronically via this new, user-friendly computer expert system," says Thompson. "We just finished a prototype project, using fruit flies, that we developed for APHIS."

He adds that the system, now undergoing trial runs, will give APHIS inspectors and plant quarantine experts "immediate access" to the latest scientific data on fruit fly species worldwide.

"The fruit fly expert system will greatly enhance our ability to expedite cargo from countries exporting commodities that could harbor fruit flies," Bech says.

BIOTA—Electronic Identification and Classification

Thompson's fruit fly expert system is just the first step in a much larger project—developing an information database called BIOTA, short for Biosystematic Information on Terrestrial Arthropods.

"The Smithsonian Institution's National Museum of Natural History

SCOTT BAUER

Lynn Carroll selects medfly specimens and related species for examination and identification. The magnified wing specimen on the computer monitor (right) can be identified using a computer-based expert system (monitor on left). (K5445-12)

The data will be updated continually by the systematic experts. When enough new information is accumulated, it will be automatically formatted and distributed to users. That will eliminate having to revise and republish a text every few years.

"Expert systems will make insect identification more flexible and verification much easier than traditional taxonomic systems that rely on text. Many types of pests can be immediately eliminated by punching in the geographic location or host data," Thompson says.

And insect characteristics are illustrated, allowing direct comparison of images with the specimen. "This speeds up identification and reduces the number of decisions that users must make. They now have to read a text and decide which insect they are identifying," he explains.

Also, for a poor or aberrant specimen, the user can ask the computer to tolerate an error or two before rejecting the insect group designation, or taxon. Errors, once detected, can be easily corrected without going through all the possibilities again.

Thompson says, "Besides saving the user time, the new system will maximize data sharing, eliminate redundant data handling, increase the speed of data processing, and lower the cost and space needed for storing data."—By **Hank Becker,** ARS.

F. Christian Thompson and Allen L. Norrbom are at the USDA-ARS Systematic Entomology Laboratory, U.S. National Museum of Natural History, Washington, DC 20560; phone (202) 382-1800, fax (202) 786-9422. ◆

has custodial responsibility for a collection of more than 30 million insect specimens. ARS and museum scientists jointly curate and add to the collection," Stoetzel says. "When completed, BIOTA will give users electronic access to the combined knowledge of all 34 SEL scientists, who are world experts on classifying and identifying insects and mites."

The core of the fruit fly identification system is information stored on CD-ROM's as color images, along with data such as a species' geographic distribution, host plants, and parasites. "A single disk can store an immense amount of data—more than 15,000 pictures of fruit flies and about 150,000 pages of information about them," Thompson says.

SCOTT BAUER

An entomologist examines a drawer of *Toxotrypana* flies, which are pests of papaya. (K5447-12)

Deer Scents May Guide Ticks to Hosts

Lyme disease, virtually unknown a decade ago, has become a major human health problem in this country. So Agricultural Research Service scientists are studying ways to control the tick that spreads it.

Lyme disease causes debilitating arthritic, heart, and neural problems in humans and dogs. "The bacterium responsible is transmitted by the bite of the black-legged tick, *Ixodes scapularis*, also known as the deer tick," says entomologist John F. Carroll.

Field studies showed that adult ticks appeared to be most numerous along deer trails. "This distribution seemed more than coincidental, and we wondered if the ticks have a way of sensing the best locations to find the hosts they need for survival and reproduction," says Carroll.

Laboratory tests designed by Carroll and ARS entomologists Edward T. Schmidtmann and Jerome A. Klun showed that adult black-legged ticks responded to substances associated with external glands found on the legs of white-tailed deer; they remained stationary on surfaces on which the glands had been rubbed.

And they reacted to doe's urine in the same manner. Deer use the glandular secretions and urine to communicate among themselves, as for marking trails.

"These results are interesting, and although not conclusive, they have prompted a search for the chemical that may be responsible for the tick's behavior," says Carroll. "It is too early to tell if these findings will result in a control method, but they may help to increase our understanding of how ticks find their hosts."

Changes in how people use and interact with the environment have contributed to the growth of the Lyme disease problem. As the city has spilled over into farm country, an interesting mosaic has appeared. There are areas of farms, forests, and housing developments—all close to each other. Since deer predators have been virtually eliminated and access to farm-grown crops has increased, white-tailed deer populations have soared.

Black-legged ticks: (left to right) Engorged female, female, and male (to right of straight pin). These life stages feed on deer.

SCOTT BAUER

White-tail deer. (K5437-1)

During the day the deer stay in the forest; at night they dine on the dinner table the farmer and suburban dweller provide them. With the deer come the ticks, and people become the accidental host for ticks looking for a blood meal.

"However unintentionally, infected ticks spread the Lyme disease bacterium to people," says Carroll.

It is ironic that deer do not even carry the disease. The tick's immature stages—larva and nymph—feed on rodents. The white-footed mouse turns out to be the real culprit, for it carries the Lyme disease bacterium.

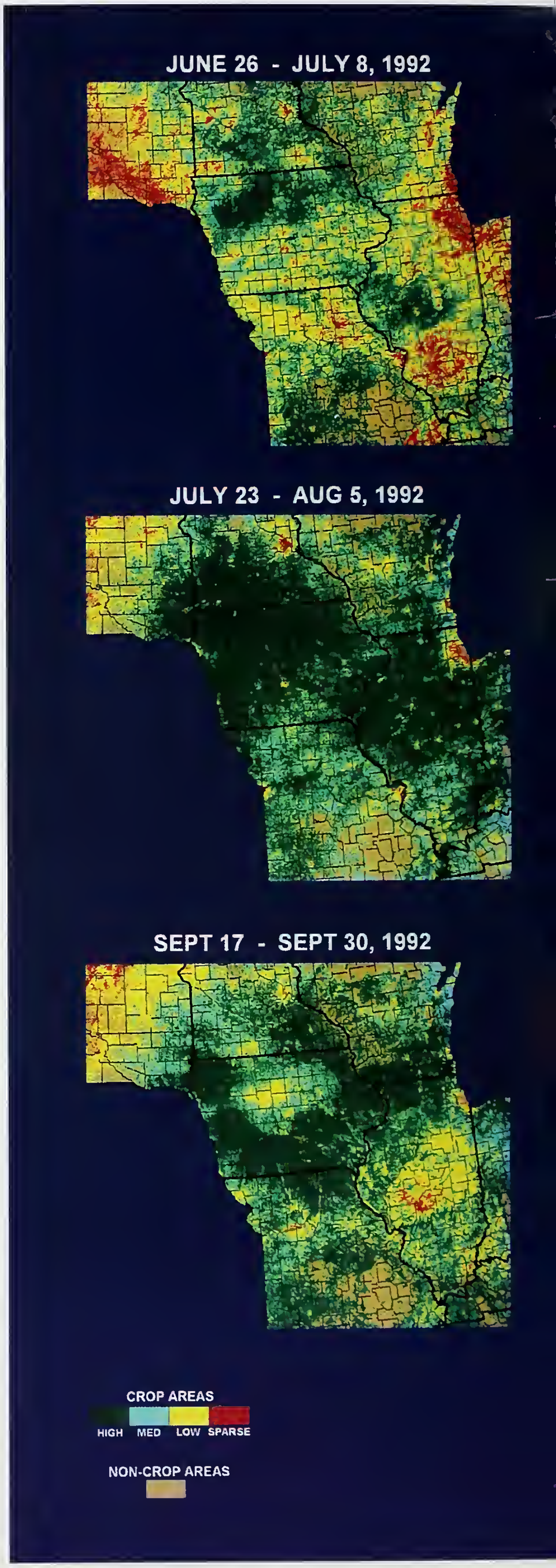
Toward the end of its 2-year life cycle, the adult tick needs to feed on a large mammal. For the black-legged tick, this usually means the white-tailed deer. The female tick requires this blood meal for egg development. After feeding, she drops off the deer, lays her eggs, and dies. The young hatch and feed on rodents, starting the life cycle over again.—By **Vince Mazzola,** ARS.

John F. Carroll and Edward T. Schmidtmann are at the USDA-ARS Livestock Insects Laboratory, Building 117C, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-9017, fax (301) 504-8881.

Jerome A. Klun is at the USDA-ARS Insect Chemical Ecology Laboratory, Building 007, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-9388, fax (301)504-6580. ◆

All stages of the deer tick will feed on people. To avoid contact, people should stay away from wooded areas, leaf litter, and bushy undergrowth. Campers and hikers should wear light-colored clothes so as to spot ticks, wear long pants and long-sleeved shirts, tuck pants cuffs into socks and shirts into pants, check often and thoroughly for ticks, change clothes when going indoors, and use repellants for skin and clothing according to directions on product labels.

After the Flood—Satellites Show Damage to Midwest Farmlands



June 26-July 8, 1993. The predominant colors for the first set of satellite images are glaring red and yellow. Rashlike, they spread across southern Minnesota, most of Iowa, northern Illinois. By September, the red has subsided, giving way to shades of green fringed, here and there, by traces of yellow.

The images and their colors may seem at first glance to be no more than eye-catching murals.

But to ARS researchers they tell a story: where, and how seriously, unprecedented flooding in the Midwest last summer affected corn, soybeans, and other crops.

ARS agricultural meteorologist Paul C. Doraiswamy produced the maps using data collected from a satellite that orbits about 537 miles above the Earth. Assigned to ARS' Remote Sensing Research Laboratory at the Beltsville (Maryland) Agricultural Research Center, he uses satellite imagery to monitor crop conditions and seasonal productivity—especially in times of natural events such as flooding, drought, or insect infestations.

During the 1993 flood, Doraiswamy and assistants Richard Strub and Wei Xia developed satellite images of the Midwest and produced them as regional and country-scale maps. The research was part of ARS' cooperative research with the USDA's National Agricultural Statistics Service (NASS).

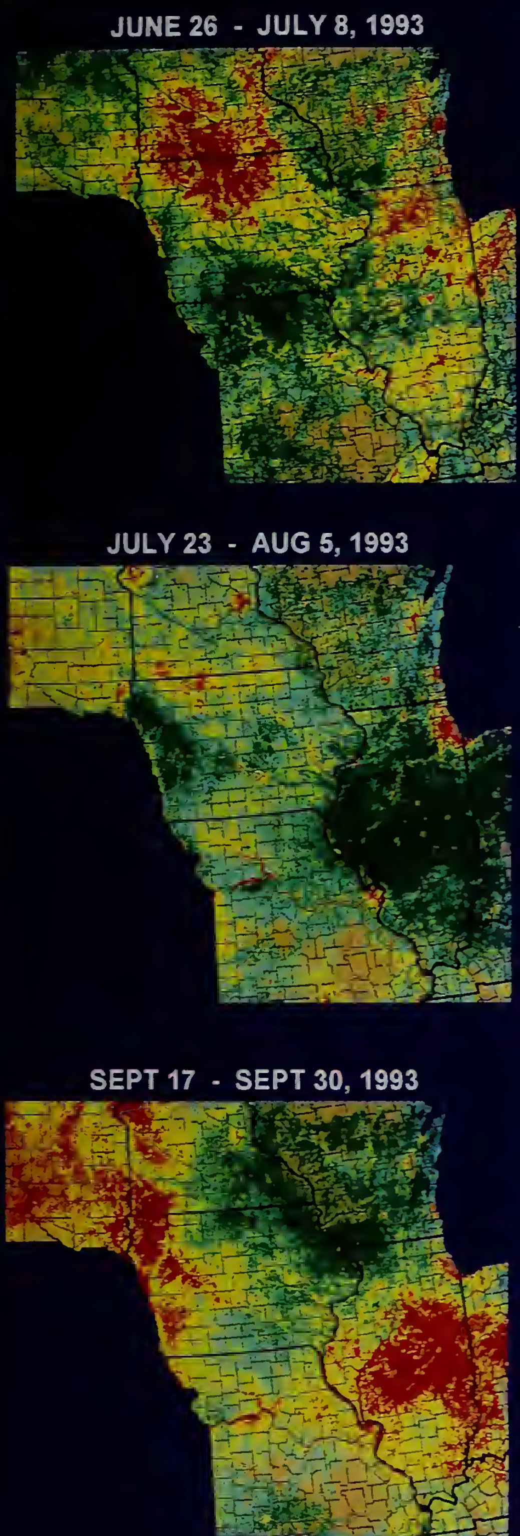
"The images showed what the growth of the crops was and how long the crops were inundated with water left from the flooding," Doraiswamy says. "We were also able to figure out which counties in the states were flooded and how much of their crop acreage was damaged."

The maps, in addition to field surveys and other means, helped NASS' monthly Agricultural Statistics Board to assess potential crop losses as a result of the flooding. These estimates, in turn, helped crop insurance agencies deliver assistance to farmers in Iowa, Illinois, Minnesota, Missouri, and other flood-affected states.

Doraiswamy furnished NASS with six of the 30- by 40-inch maps—one every 2 weeks, from early June to late August. Each was color coded to display the relative abundance or scarcity of vegetation according to how the flooding affected crop growth. The colors, Doraiswamy says, corresponded to a normalized-difference vegetation index based on the satellite's measurements of specific light wavelengths reflected by the vegetation. Colors for the maps ranged from green—showing regions with healthy, dense vegetation—to red, indicating sparse, slower growing vegetation.

"The seasonal change in the index tells you how well the crops are doing at particular stages of their development," Doraiswamy says. He determined the extent to which flooding affected crop growth by comparing the vegetation difference for each bi-weekly period between the 1993 maps and those for 1992. Based on maps for July 1993, for example, he estimates that heavy rainfall and flooding affected—but did not destroy—about 20 million acres of corn and soybean crops in Iowa, Illinois, Minnesota, and Missouri.

According to a NASS Crop Production report for August that was based on both direct and satellite observation, crops were actually destroyed on about 1,250,000 acres



Satellite images of the upper Mississippi River region for selected biweekly periods during the 1992 and 1993 crop season. The predominance of red and yellow in the earlier 1993 maps reflects sparse vegetation from a cool, wet spring and subsequent flooding. (K5480-1&2)

of corn and soybeans in Iowa; 600,000 in Illinois; 900,000 in Minnesota; and 850,000 in Missouri. Kansas, Nebraska, North Dakota, South Dakota, and Wisconsin also sustained crop losses from the flooding.

As of March 3, 1994, USDA emergency assistance to the nine affected states totaled about $2.3 billion, says a report from the USDA Flood Information Center in Washington, D.C. Of funds for wastewater cleanup, livestock feed, soil conservation, and other flood-induced emergencies, about $1.2 billion went toward disaster programs for low-yield crops. Payment for crop insurance for farmers was $1 billion.

Other than destroying crops altogether, flooding typically reduced yields by delaying the crops' development and by carrying away nitrogen fertilizer and other nutrients from the fields through runoff. On the maps—especially those for early June and July—such areas appear as yellow and, in more severe cases, as red because of delayed crop development.

Some of the worst-hit crops were grown in the upper Mississippi Valley or near the lower Missouri River—regions where excessive rainfall early last June prompted the heaviest flooding.

NOAA and the Flood

NOAA-AVHRR—a satellite equipped with an "Advanced Very High Resolution Radiometer" sensor—generated data for the maps' color indices. ARS uses several such satellites, thanks to cooperative research agreements with the National Oceanic and Atmospheric Administration.

"NOAA-AVHRR is one of three major satellites most commonly used by researchers for assessing natural resources," Doraiswamy says. [SPOT and LANDSAT are the other two.] "I used data from the NOAA-AVHRR satellites so I could look at large areas on a daily basis."

The satellite, he notes, also afforded the opportunity to observe the flood's cumulative effect on development of crops throughout the 1993 growing season—a feat virtually impossible with field-by-field surveys.

As it passed over the Midwest each day, the satellite measured the spectral reflectance of radiation in visible and near infrared wave bands reflected off water, soil, and any vegetation within each 105-acre square.

Once collected, the measurements were periodically beamed by satellite to computers operated by the U.S. Geological Survey's EROS (Earth Resources Observation Service) Center at Sioux Falls, South Dakota. The ARS lab obtained these measurements as both raw and processed data every 2 weeks

Special computer software at the ARS lab later categorized the radiation measurements for computing the biweekly changes in the amount of green vegetation reported on the maps.

Doraiswamy says they then took that digital information, calibrated it, and converted it into images using the Land Analysis System software developed by National Aeronautics and Space Administration researchers at the Goddard Space Flight Center in Greenbelt, Maryland. The software also projected the images onto the maps and shaded them according to the relative vigor and density of vegetation on the ground.

Doraiswamy plans to combine the software with agro-climatic models that use weather data to rapidly assess crop conditions and forecast yield estimates. That could help statistics-gathering agencies like NASS or USDA's Foreign Agricultural Service to keep a closer watch on U.S. and foreign crop production throughout the growing season.—By **Jan Suszkiw,** ARS.

Paul C. Doraiswamy is with the USDA-ARS Remote Sensing Research Laboratory, Bldg. 001, Beltsville Agricultural Research Center, 10300 Baltimore Ave., MD 20705-2350; phone (301) 504-6576, fax (301) 504-5031. ◆

Fish Fed Corn Byproducts Taste Good

Good-tasting fish filets can come from fish fed byproducts of ethanol production. And that's good news for both corn and fish producers.

Tilapia fish raised on pellets containing between 16 and 19 percent added corn distillers grain and soy flour tasted the same as fish on commercial fish feed, according to ARS food technologist Kathleen Warner in Peoria, Illinois. Warner coordinates sensory panel evaluations at the National Center for Agricultural Utilization Research (NCAUR).

Tilapia are perchlike fish native to the warm waters of the Euphrates River and the Sea of Galilee in Asia. Other additives used in the study also included corn gluten meal and corn gluten feed.

"In previous sensory analyses on the ethanol byproducts themselves, our panelists described the flavor and odor as musty, fermented, and much like stale beer. But when low-to-moderate levels of the additives were incorporated into standard fish feed, the panelists reported no carry-over of any of the undesirable flavors in the cooked filets," says Warner.

"The cost of producing extruded fish feed on the farm could be less than the commercial price depending on the amount produced," says Patrick D. O'Rourke, an Illinois State University agricultural economist. Research is in progress to determine the volume necessary to make on-farm extrusion of fish feeds most economical for farmers. Results will be available by the fall of 1994.

This is good news for fish producers. Feed now represents 40 to 60 percent of the cost of aquaculture. Grains are much cheaper than conventional feeds.

In cooperative aquaculture studies at Illinois State University, researcher Ron Rosati extruded the alcohol byproducts into pellets and fed tilapia fish the grain diet formulated by ARS chemists Y. Victor Wu and David J. Sessa, in collaboration with fish nutritionist Paul Brown of Purdue University. Harvested fish filets were later sent to NCAUR for sensory panel evaluations and compositional analyses.

Adding higher levels of alcohol byproducts from corn made the filets taste musty, less sweet, and more fishy. The fishy flavor is a characteristic that Warner says is related to storage and handling.

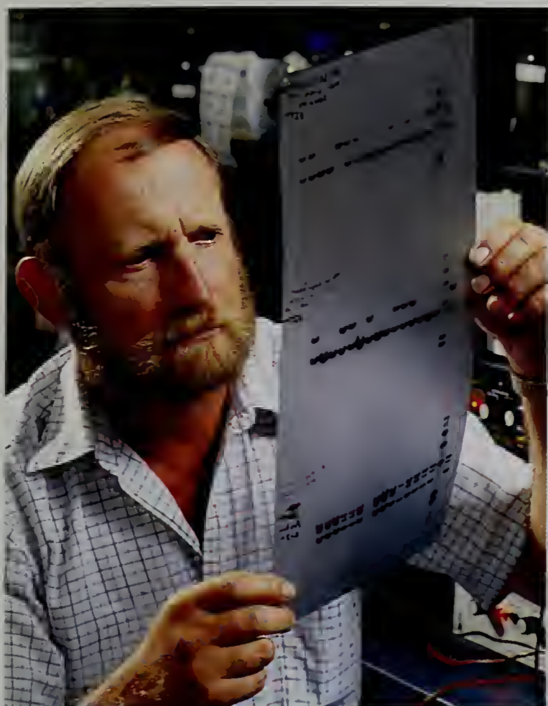
The fish feed market gives Midwest farmers an added demand for their corn and soybeans. Using grain to supply the growing aquaculture industry could relieve ocean-depleting demands for shrimp and fish.

In these cooperative studies, Wu, Rosati, Sessa, and Brown found that lowering protein levels in fish fed the grain ration didn't hinder tilapia growth. The Peoria scientists plan to continue lowering protein levels in the formulation, which is expected to further reduce the cost of making corn and soybean-based fish feed.—By **Linda Cooke,** ARS.

Kathleen Warner is in the USDA-ARS Food Quality and Safety Research Unit, and Y. Victor Wu and David J. Sessa are in the USDA-ARS Biopolymer Research Unit, National Center for Agricultural Utilization Research, 1815 N. University Street, Peoria, IL 61604; phone (309) 681-6584 (Warner), (309) 681-6351 (Wu and Sessa), fax (309) 681-6686. ◆

Science Update

KEITH WELLER



Using a DNA probe, animal physiologist Roger Stone examines film showing genotypes of specific animals. (K4287-10)

First Livestock Gene Maps

ARS scientists have completed research for the world's first genetic maps for cattle and swine. In 5 to 10 years, ARS expects information from the maps to help the livestock industry. Breeders and researchers now rely heavily on performance and pedigrees to identify animals with specific desirable genetic makeups, such as those that translate into improved meat quality and disease resistance. The new maps link hundreds of genetic markers—identifiable bits of DNA that serve as useful signposts—along the chromosomes of cattle and swine. When scientists identify which markers lie near genes or gene groups that control important traits, they can develop biotechnology to enable more precise selection of breeding animals. The ARS researchers developed a computer database for correlating map data with important traits. Other researchers can now access the database. *Craig W. Beattie, USDA-ARS Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, Nebraska; phone (402) 762-4359.*

Florida Citrus Company Licenses "A-Peeling" Process From ARS

Berry Citrus of Winter Haven, Florida, has licensed ARS' patented method for using a natural enzyme to remove the peel—including the albedo—from oranges and grapefruit. You've encountered the albedo if you've ever hand-peeled these fruits; it's the white, spongy part of the peel that clings stubbornly to the fruit. A few years ago, ARS scientists invented this method that uses an enzyme called pectinase to yield nutritious, whole fresh fruit and sections with no loss of flavor or juice. The ARS method isn't meant to replace your everyday hand peeling but is a simpler way for the food industry to supply fresh-peeled citrus sections. Obtaining those products has required steaming, machine peeling and soaking of fruit in hot lye, and cutting by hand—which often wastes juice and adversely affects flavor. *Robert A. Baker, USDA-ARS Citrus and Subtropical Products Laboratory, Winter Haven, Florida; phone (813) 293-4133.*

Yugoslavian Plants Adapt to Midwest Landscape

Midwestern residents may someday enjoy a wider variety of winter-hardy trees and shrubs. In the mid-1970's, scientists collected hundreds of specimens of landscape plants from several areas of the old Yugoslavia. Many of the plants still thrive at test sites in the Midwest, and seeds or cuttings are available as parent stock to researchers, nurseries, and public gardens. Species include the European cranberry bush, Austrian pine, Scotch pine, and hedge maple. *Mark P. Widrlechner, ARS-USDA North Central Regional Plant Introduction Research Station, Ames, Iowa; phone (515) 292-6507.*

New Southern Soybean Wards Off Nematodes, Other Pests

Lyon, a new soybean variety, resists race 3 soybean cyst nematodes and stem canker, major problems in Southern soybean production. ARS developed Lyon in cooperation with Mississippi State University. Its yields match those of other popular varieties, and its range of pest resistance is broader. Lyon also resists root knot nematodes, leaf-feeding insects, bacterial pustule, and phytophthora rot. Foundation seed is available from Mississippi Foundation Seed Stocks. *Edgar E. Hartwig, ARS-USDA Soybean Production Research Unit, Stoneville, Mississippi; phone (601) 686-9311.*

New Pink Phlox and Red Raspberry

Helene phlox and Plainsman red raspberry, two hardy plants for the northern Great Plains, are now available from ARS to researchers and nursery operators. Both were developed by retired ARS horticulturist Gene S. Howard. Growing 24 to 30 inches tall, Helene phlox sports pink, fragrant flowers on 12 to 20 stems. Plainsman raspberry, which traces part of its heritage to native Wyoming plants, bears fruit from early August until heavy frost. *Gerald E. Schuman, USDA-ARS High Plains Grasslands Research Station, Cheyenne, Wyoming; phone (307) 772-2433.*

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Upcoming in the JUNE Issue

- Wind is an invisible two-edged sword that ARS scientists are struggling to master. Current research aims both at minimizing wind-driven soil erosion and capturing wind power to generate energy for agricultural uses.

- More powerful and versatile than its predecessor, a new computer simulation enables farmers to use physical environment data to predict important wheat production outcomes.

- A new soybean variety with less day-length sensitivity and a wider latitude range may soon be available. Field tests this year will determine whether it will be released as germplasm for breeders or as a named variety for southern growers.